Experimental study of the effect of charge on ultrafine particle deposition

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1 Introduction

The health effects of ultrafine particles (UFPs, <100 nm) have received increasing attention in recent years and particles from a variety of indoor sources, such as combustion or printer emissions, fall within this size range. Since people spend most of their time indoors, knowledge on aerosol deposition in the human respiratory tract is essential to minimise the health risks associated with environmental or occupational exposure to aerosol particles. Among the factors that could alter particle deposition, electrical charge is important as it may increase particle deposition in human respiratory tract (Melanderi et al., 1983), even when particles carry only a few charges. However, evidence showing such an increase in particle deposition for UFPs is sparse. The aim of this study was to investigate the effect of charge on the deposition of UFPs in the human lung by studying the deposition of charged particles in the conductive tubing of an experimental laboratory system.

2 Materials/Methods

A nebuliser (Model CN241, BGI Inc., US) was used to generate polydisperse diethyl-hexyl-sebacate (DEHS) particles. A Scanning Mobility Particle Sizer (SMPS) was used to measure particle size distribution and particle number concentration (PNC) was measured by both an SMPS and a TSI 3010 Condensation Particle Counter (CPC). The SMPS is comprised of a CPC and a 3071 Electrostatic Classifier (EC). An ioniser (AH-202, Aironic, US) inside the chamber was used to charge the DEHS particles, and an Aerosol Electrometer (AE, TSI Model 3068) was used to measure particle charge.

In order to investigate the effect of charge on particle deposition in the tube, three aerosols were compared:

- **Charged**: generated by nebuliser, then charged by ioniser;
- **Non-charged**: generated by nebuliser;
- **Charge neutralised**: generated by nebuliser and then passed through an ^{85}Kr bi-polar charger.

A sampling box (9 L) was connected to the end of the tube (L: 85 cm; D: 1.7 cm), which acted as a reservoir to avoid measuring the artefacts produced by flow fluctuation. The aerosols were drawn through the tube from the large chamber ($1m^3$) into the sampling box at a flow rate of 7.5 L/min. Particle number concentration and charge were measured by the CPC and AE, respectively, both before and after the aerosols were drawn through the tube. For each of the three aerosols, particle deposition was determined by comparing the particle number concentration difference before and after the aerosol passed through the plastic tube. The average of three to five measurements was taken as the final deposition value.

3 Results and Discussion

In this study, the effect of charge on the measuring efficiencies of each instrument, as well as on particle deposition was investigated.

As shown in Table 1, there was a dramatic decrease in the concentration (74.9 ± 10.1) of charged particles when they were measured by the SMPS. However, the decrease in concentration was only 2.9 ±1. 4 when measured by a CPC. Since a negative polarity of voltage was applied to the central rod of the DMA used in this study, only positively charged particles were classified and detected by the SMPS. Furthermore, the ioniser used in this study was a unipolar charger and therefore, the particles

were mainly negatively charged. Based on the above, we hypothesised that the neutraliser (bi-polar charger) was overwhelmed by the negatively charged particles and could not discharge the most negatively charged particles into a Boltzmann distribution. Therefore, only a few particles were detected by the SMPS when the particles were charged by the ioniser. In light of this situation, only the CPC was used to measure particle deposition in the later stages of the experiment.

Table 1. Reading comparison between SMPS and CPC

SMPS reading		**CPC reading**	
PNC Drop (%)	**PNC ($x 10^2$ cm^{-3}) Before/ after ionised**	**Drop rate (%)**	**PNC ($x 10^2$ cm^{-3}) Before/ after ionised**
84.1	468/74.6	2.5	282/275
76.1	461/110	1.0	418/414
84.9	754/114	4.1	441/423
61.9	923/352	3.8	369/355
67.7	296/95.5		
74.9±10.1		**2.9±1.4**	

Table 2. Comparison of deposition increase

DI	**Subject**	**Particle**	**Literature**
1.78 Charged/ Non-charged	PE tube	DEHS Polydisperse (CMD 90nm)	Current study
2.3 Singly charged/ neutralised	Metal cast	FAH Monodisperse 125 nm	Cohen et al., 1998
1.15-1.3 29-66e/3e	Human lung	Carnauba wax Monodisperse 0.33-1 um	Melanderi et al., 1983
1.25 Non-charged/ Neutralised	Rat lung	TiO2 Polydisperse 0.5 um	Ferin et al., 1983

DI: Deposition increase, ratio of deposition fraction between particles with different charges
Non-charged: nebuliser generated particles, or mechanical dispersion of powers
PE: polyethylene
FAH: Fluorescein-ammonium hydroxide

Only the comparison between the deposition fraction of charged and non-charged particles is reported here. As can be seen form Table 2, the deposition of charged particles increased 78% compared with non-charged particles. The increase in deposition for UFPs was generally higher than those of submicron particles. However, it is too early to conclude that charge has greater effect on lung deposition for UFPs than for larger particles, since the difference could be a result of conducting in vitro experiments (i.e. the plastic tube used this study or the metal cast used by Cohen et al., 1998) versus in vivo experiments (i.e. the rats studies in Ferin et al., 1983 and the humans studied in Melandri et al., 1983). Further in vivo experiments are needed to confirm this hypothesis.

4 Conclusions

Although an increase in particle deposition was observed in the tube after the particles were charged by an ioniser, the mechanisms responsible for the phenomenon are not clear due to a lack of charge distribution data. Therefore, further experiments are needed to investigate the effect of charge on deposition (especially in different sites/regions) in human lung for particles with a known charge distribution.

5 References

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